5.0 Potential Radiological Doses from 1998 Hanford Operations

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During 1998, radionuclides reached the environment in gaseous and liquid effluents from Hanford Site operations. Monitored gaseous effluents were released from operating stacks and ventilation exhausts. Other potential sources include fugitive emissions from contaminated soil areas and unmonitored facilities. Liquid effluents were released from operating wastewater treatment facilities and from contaminated groundwater seeping into the Columbia River.

Potential radiological doses to the public from these releases were evaluated in detail to determine compliance with pertinent regulations and limits. Dose calculation methodology is discussed in Appendix D. The radiological impacts of 1998 Hanford operations were assessed in terms of the following:

- dose to a hypothetical, maximally exposed individual at an offsite location
- maximum dose rate from external radiation at a publicly accessible location on or within the site boundary
- dose to an avid sportsman who consumes wildlife that may have acquired contamination from radionuclides on the site
- total dose to the population residing within 80 km (50 mi) of the Hanford operating areas
- absorbed dose rate (rad/d) received by animals caused by radionuclide releases to the Columbia River.

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide activities in the surrounding environment. However, the amounts of most radioactive materials released during 1998 from Hanford sources were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the measurable radionuclides, it was difficult to identify the contributions from Hanford sources in the presence of contributions from worldwide fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using the Generation II (GENII) computer code Version 1.485 (PNL-6584) and Hanford Site-specific parameters listed in Appendix D and in PNNL-12088, APP. 1 to calculate activities of radioactive materials in the environment from effluent releases reported by the operating contractors.

As in the past, radiological doses from the water pathway were calculated based on the differences in radionuclide activities between upstream and downstream sampling points. During 1998, tritium, iodine-129, and uranium were found in the Columbia River downstream of Hanford at greater levels than predicted based on direct discharges from the 100 Areas. All other radionuclide activities were lower than those predicted from known releases. Riverbank springs water, containing these radionuclides, is known to enter the river along the portion of shoreline extending from the Old Hanford Townsite downstream to the 300 Area (see Section 4.2, "Surface Water and Sediment Surveillance" and Section 6.1, "Hanford Groundwater Monitoring Project"). No direct discharges of radioactive materials from the 300 Area to the Columbia River were reported in 1998.

The estimated dose[a] to the maximally exposed, offsite individual from Hanford operations in 1998 was 0.02 mrem (2×10^{-4} mSv) compared to 0.01 mrem

(a) Unless stated otherwise, the term "dose" in this section is the "total effective dose equivalent" (see Appendix B, "Glossary").

(1×10^{-4} mSv) reported for 1997. The dose to the local population of 380,000 (PNL-7803) from 1998 operations was the same as reported for 1997, 0.2 person-rem (0.002 person-Sv) (Section 5.0 in PNNL-11472). The 1998 average dose to the population was approximately 0.0005 mrem (5×10^{-6} mSv) per person (the same as 1997). The current U.S. Department of Energy (DOE) radiological dose limit (DOE Order 5400.5) for an individual member of the public is 100 mrem/yr (1 mSv/yr) from all pathways, which includes the U.S. Environmental Protection Agency's (EPA's) limit of 10 mrem/yr (0.1 mSv/yr) from airborne radionuclide emissions (Title 40, Code of Federal Regulations, Part 61 [40 CFR 61]). The national average radiological dose from natural sources is approximately 300 mrem/yr (3 mSv/yr) (National Council on Radiation Protection and Measurements 1987). Thus, 1998 Hanford emissions potentially contributed to the maximally exposed individual a dose equivalent to only 0.02% of the DOE dose limit, 0.2% of the EPA limit, or 0.006% of the average dose received from natural radioactivity in the environment. For the average member of the local population, these contributions were approximately 0.0005%, 0.005%, and 0.0002%, respectively.

The uncertainty associated with the radiological dose calculations on which this report is based has not been quantified. However, when Hanford-specific data were not available for parameter values (e.g., vegetation uptake and consumption factors), conservative values were selected from the literature for use in environmental transport models. Thus, radiological doses calculated using environmental models should be viewed as hypothetical maximum estimates of doses resulting from Hanford operations.

5.0.1 Maximally Exposed Individual Dose

The maximally exposed individual is a hypothetical person who lives at a location and has a lifestyle such that it is unlikely that other members of the public would receive a higher radiological dose. This individual's diet, dwelling place, and other factors were chosen to maximize the combined doses from all reasonable environmental pathways of exposure to radionuclides in Hanford Site effluents. In reality, such a combination of maximized parameters is highly unlikely to apply to any single individual.

The hypothetical location of the maximally exposed individual can vary from year to year, depending on the relative contributions of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities. Historically, two separate locations have been used to assess the dose to the maximally exposed individual: 1) the Ringold area, 26 km (16 mi) east of separations facilities in the 200 Areas and 2) the Riverview area across the river from Richland (Figure 5.0.1). The Ringold area is closer than Riverview to Hanford facilities that historically were major contributors of airborne effluents. At Riverview, the maximally exposed individual has the highest exposure to radionuclides in the Columbia River.

Since 1993, a third location across the Columbia River from the 300 Area has been considered. Because of the shift in site operations from strategic materials production to the current mission of developing waste treatment and disposal technologies and cleaning up contamination, the significance of the air emissions from the production facilities in the 200 Areas has decreased relative to those from the 300 Area. Therefore, a receptor directly across the river from the 300 Area, at Sagemoor, would be maximally exposed to airborne radionuclides from those facilities. The applicable exposure pathways for each of these locations are described below.

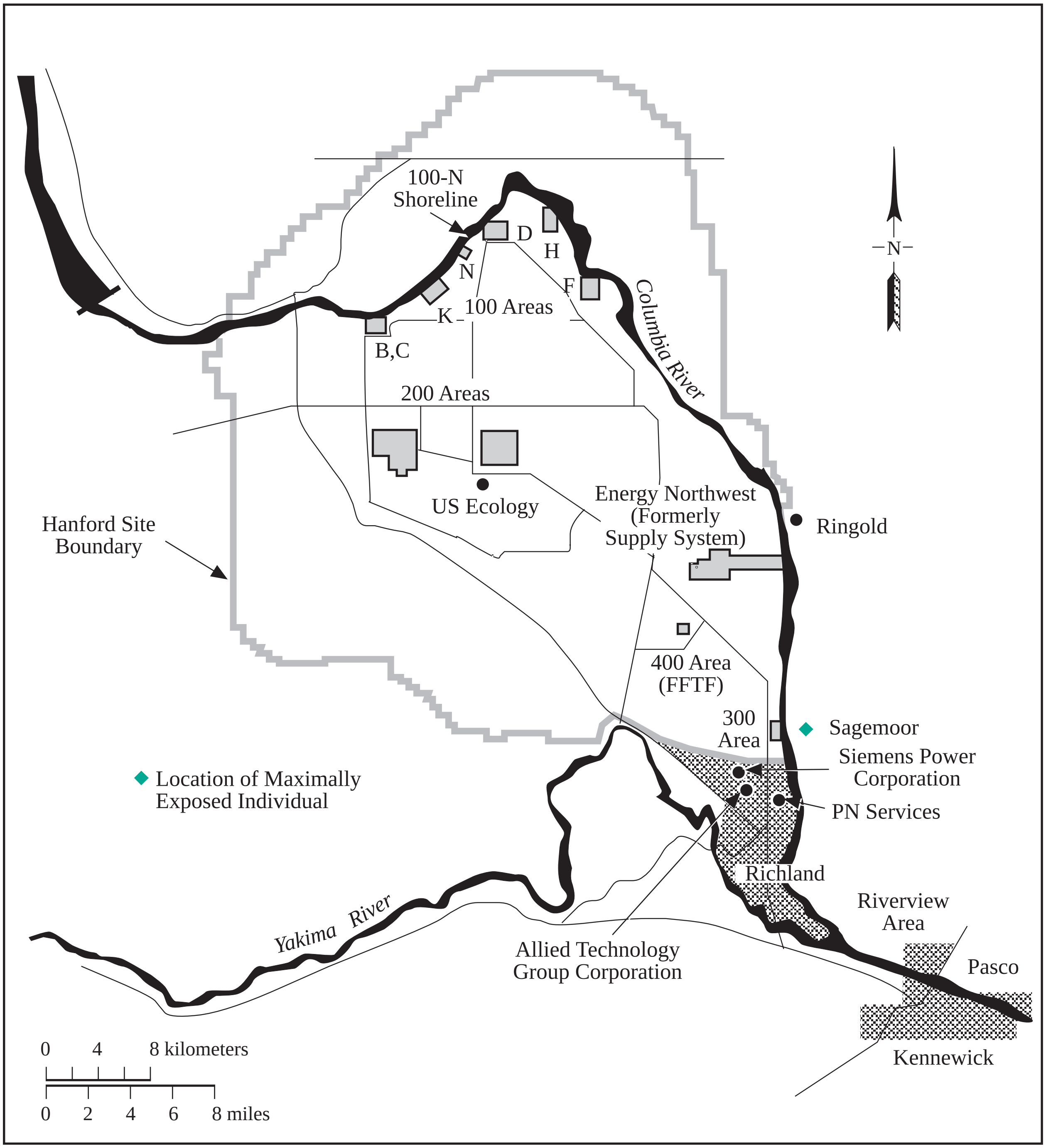

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Figure 5.0.1. Locations Important to Dose Calculations

The Ringold area is situated to maximize air pathway exposures from emissions in the 200 Areas, including direct exposure to the plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of locally grown food products. In addition, it is assumed that individuals at Ringold irrigate their crops with water taken from the Columbia River downstream of where groundwater enters the river from the 100 and 200-East Areas (discussed in Section 6.1, "Hanford Groundwater Monitoring Project"). This results in additional exposures from ingestion of irrigated food products and external irradiation from radionuclides deposited on the ground by irrigation. Recreational use of the Columbia River is also considered for this individual, resulting in direct exposure from water and radionuclides deposited on the shoreline and internal dose from ingestion of locally caught fish.

The Riverview area receptor is assumed to be exposed via the same pathways as the individual at Ringold, except that irrigation water from the Columbia River may contain radionuclides that enter the river at the 300 Area, in addition to those from upstream release points. This individual is also assumed to obtain domestic water from the river via a local water treatment system. Exposure of this individual from the air pathway is typically lower than exposure at Ringold because of the greater distance from the major, onsite, air emission sources.

The individual at Sagemoor, assumed to be located 1.5 km (1 mi) directly across the Columbia River from the 300 Area, receives the maximum exposure to airborne effluents from the 300 Area, including the same pathways as the individual at Ringold. Domestic water at this location comes from a well rather than from the river, and wells in this region are not contaminated by radionuclides of Hanford origin (EPS-87-367A). Although the farms located across from the 300 Area obtain irrigation water from upstream of the Hanford Site, the conservative assumption was made that the diet of the maximally exposed individual residing 1.5 km (1 mi) east of the 300 Area consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both liquid and gaseous effluents. The added contribution of radionuclides in the Riverview irrigation water maximizes the calculated dose from the air and water pathways combined.

The 1998 hypothetical, maximally exposed individual at Sagemoor was calculated to have received a slightly higher dose (0.022 mrem/yr) than the maximally exposed individual located at either Ringold (0.009 mrem/yr) or Riverview (0.012 mrem/yr). Radiological doses to the maximally exposed individual were calculated using the effluent data in Tables 3.1.1 and 3.1.4. Quantities of radionuclides assumed to be present in the Columbia River from riverbank springs were also calculated for input to the GENII code. The estimated releases to the river from these sources were derived from the difference between the upstream and downstream activities. These radionuclides were assumed to enter the river through groundwater seeps between the Old Hanford Townsite and the 300 Area.

The calculated doses for the hypothetical, maximally exposed individual (at Sagemoor) in 1998 are summarized in Table 5.0.1. These values include the doses received from exposure to liquid and airborne effluents during 1998, as well as the future, or committed dose from radionuclides that were inhaled or ingested during 1998. As releases from facilities and the doses from these sources decrease, the contribution of diffuse sources such as wind-blown contaminated soil becomes relatively more significant. An upper estimate of the dose from diffuse sources is discussed in Section 5.0.3, "Comparison with Clean Air Act Standards." The estimated dose from diffuse sources was similar to the dose reported in Table 5.0.1 for measured emissions. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix D (Tables D.1, D.2, and D.4, respectively).

Table 5.0.1. Dose to the Hypothetical, Maximally Exposed Individual Residing at Sagemoor from 1998 Hanford Operations

		Dose Contributions from Operating Areas, mrem				
Effluent	**Pathway**	**100 Areas**	**200 Areas**	**300 Area**	**400 Area**	**Pathway Total**
Air	External	1.2×10^{-8}	8.8×10^{-8}	2.2×10^{-8}	1.9×10^{-8}	1.4×10^{-7}
	Inhalation	6.6×10^{-6}	1.6×10^{-4}	1.4×10^{-3}	1.4×10^{-5}	1.6×10^{-3}
	Foods	2.9×10^{-7}	2.8×10^{-5}	1.3×10^{-2}	9.4×10^{-5}	1.3×10^{-2}
	Subtotal air	6.9×10^{-6}	1.9×10^{-4}	1.4×10^{-2}	1.1×10^{-4}	1.5×10^{-2}
Water	Recreation	1.7×10^{-6}	3.2×10^{-5}	0.0[a]	0.0	3.4×10^{-5}
	Foods	8.5×10^{-4}	3.7×10^{-3}	0.0	0.0	4.6×10^{-3}
	Fish	7.0×10^{-4}	2.4×10^{-3}	0.0	0.0	3.1×10^{-3}
	Drinking water	0.0	0.0	0.0	0.0	0.0
	Subtotal water	1.6×10^{-3}	6.1×10^{-3}	0.0	0.0	7.7×10^{-3}
Combined total		1.6×10^{-3}	6.3×10^{-3}	1.4×10^{-2}	1.1×10^{-4}	2.2×10^{-2}

(a) Zeros indicate no dose contribution to maximally exposed individual through water pathway.

The total radiological dose to the hypothetical, maximally exposed, offsite individual in 1998 was calculated to be 0.02 mrem (2×10^{-4} mSv) compared to 0.01 mrem (1×10^{-4} mSv) calculated for 1997. The primary pathways contributing to this dose (and the percentage of all pathways) were the following:

- consumption of foods grown downwind of the 300 Area (59%), principally tritium released from the 300 and 400 Areas
- consumption of food irrigated with Columbia River water or fish from the Columbia River (27%), principally isotopes of uranium and tritium.

The DOE radiological dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr) (DOE Order 5400.5). The dose calculated for the maximally exposed individual for 1998 was 0.02% of the DOE limit. Thus, the Hanford Site was in compliance with applicable federal and state regulations.

The doses from Hanford operations for the maximally exposed individual for 1993 through 1998 are illustrated in Figure 5.0.2. During each year, the doses were estimated using methods and computer codes previously described. In 1992, the maximally exposed individual was located at Riverview. For 1993 through 1998, the hypothetical, maximally exposed individual was located across the Columbia River from the 300 Area at Sagemoor.

5.0.2 Special Case Exposure Scenarios

Exposure parameters used to calculate the dose to the maximally exposed individual are selected to define a high-exposure scenario that is unlikely to occur. Such a scenario does not necessarily result in the highest conceivable radiological dose. Low-probability exposure scenarios exist that could

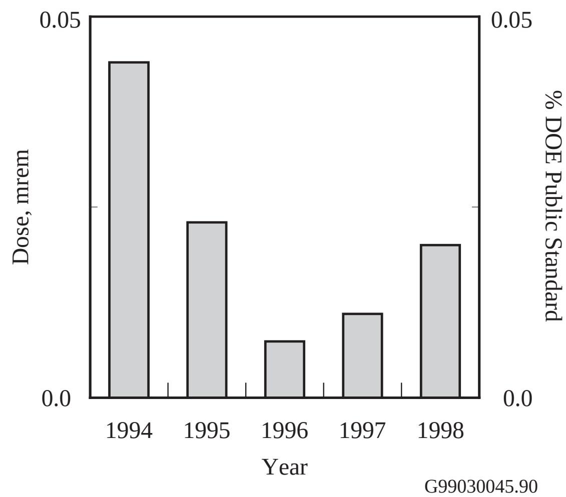

Figure 5.0.2. Calculated Dose to the Hypothetical, Maximally Exposed Individual, 1994 Through 1998

result in somewhat higher doses. Three scenarios that could potentially lead to larger doses include 1) an individual who would spend time at the site boundary location with the maximum external radiological dose rate, 2) a sportsman who might consume contaminated wildlife that migrated from the site, and 3) a consumer of drinking water at the Fast Flux Test Facility in the 400 Area.

5.0.2.1 Maximum "Boundary" Dose Rate

The boundary radiological dose rate is the external radiological dose rate measured at publicly accessible locations on or near the site. The boundary dose rate was determined from radiation exposure measurements using thermoluminescent dosimeters at locations of expected elevated dose rates on the site and at representative locations off the site. These boundary dose rates should not be used to calculate annual doses to the general public because no one can actually reside at any of these boundary locations. However, these rates can be used to determine the dose to a specific individual who might spend some time at that location.

External radiological dose rates measured in the vicinity of the 100-N, 200, 300, and 400 Areas are described in Section 4.7, "External Radiation Surveillance." Results for the 200 Areas were not used because these locations are not accessible to the public. Radiation measurements made at the 100-N Area shoreline (see Figure 5.0.1) were consistently above the background level and represent the highest measured boundary dose rates. The Columbia River provides public access to an area within approximately 100 m (330 ft) of the N Reactor and supporting facilities.

The dose rate at the location with the highest exposure rate along the 100-N Area shoreline during 1998 was 0.02 mrem/h (2×10^{-4} mSv/h), or approximately twice the average background dose rate of 0.01 mrem/h (1×10^{-4} mSv/h) normally observed at other shoreline locations. Therefore, for every hour someone spent at the 100-N Area shoreline during 1998, the external radiological dose received from Hanford operations would be approximately 0.01 mrem (1×10^{-4} mSv) above the natural background dose. If an individual spent 2 h at this location, a dose would be received that is similar to the annual dose calculated for the hypothetical, maximally exposed individual at Sagemoor. The public can approach the shoreline by boat but they are legally restricted from stepping onto the shoreline. Therefore, an individual is unlikely to remain on or near the shoreline for an extended period of time.

5.0.2.2 Sportsman Dose

Wildlife have access to areas of the site that contain radioactive materials, and some do become contaminated. Sometimes contaminated wildlife travel off the site. Sampling is conducted on the site to estimate the maximum contamination levels that might possibly exist in animals hunted off the site. Because this scenario has a relatively low probability of occurring, these doses are not included in the maximally exposed individual calculation.

Listed below are estimates of the radiological doses that could have resulted if wildlife containing the maximum levels measured in onsite wildlife in 1998 migrated off the site, were hunted, and were eaten.

- The dose from eating 1 kg (2.2 lb) of sucker or carp fillets that contains the maximum cesium-137 activity (0.04 pCi/g) measured in samples collected from the Hanford Reach of the Columbia River in 1998 is estimated to be 2 x 10^{-2} mrem (2 x 10^{-5} mSv).
- The dose from eating 1 kg (2.2 lb) of pheasant meat that contains the maximum cesium-137 activity (0.018 pCi/g) measured in samples collected on the site in 1998 is estimated to be 9 x 10^{-4} mrem (9 x 10^{-6} mSv).
- The dose from ingesting 1 kg (2.2 lb) of venison that contains the maximum cesium-137 activity (0.005 pCi/g) measured in a sample harvested on the site in 1998 is estimated to be 3 x 10^{-4} mrem (3 x 10^{-6} mSv).

These are very low doses and do not exceed the hypothetical, maximally exposed individual dose at Sagemoor. In fact, the hypothetical person who ate 1 kg (2.2 lb) of sucker or carp fillets at the maximum measured cesium-137 activity would receive the same dose as the maximally exposed individual located at Sagemoor. A person would have to consume 22 kg (48 lb) of pheasant meat or 66 kg (145 lb) of venison that contain the maximum measured cesium-137 activity to receive the same dose as the hypothetical, maximally exposed individual at Sagemoor. The methodology for determining doses from consumption of wildlife was to multiply the maximum activity measured in edible tissue by a dose conversion factor for ingestion of that flesh, which is addressed in more detail in PNL-7539.

5.0.2.3 Fast Flux Test Facility Drinking Water

During 1998, groundwater was used as drinking water by workers at the Fast Flux Test Facility in the 400 Area. Therefore, this water was sampled and analyzed throughout the year in accordance with applicable drinking water regulations (40 CFR 61). All annual average radionuclide activities measured during 1998 were well below applicable drinking water standards, but tritium was detected at levels greater than typical background values (see Section 4.3, "Hanford Site Drinking Water Surveillance," and Appendix D). Based on the measured groundwater well concentrations, the potential dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 L/d [0.26 gal/d] for 240 working days) would be approximately 0.02 mrem (0.0002 mSv). Although the hypothetical Fast Flux Test Facility worker would receive approximately the same dose as the 1998 offsite maximally exposed individual, the dose is well below the drinking water dose limit of 4 mrem for public drinking water supplies.

5.0.3 Comparison with Clean Air Act Standards

Limits for radiation dose to the public from airborne radionuclide emissions at DOE facilities are provided in 40 CFR 61, Subpart H. The regulation specifies that no member of the public shall receive a dose of >10 mrem/yr (0.1 mSv/yr) from exposure to airborne radionuclide effluents, other than radon, released at DOE facilities (EPA 520/1-89-005). The regulation also requires that each DOE facility submit an annual report that supplies information about atmospheric emissions for the preceding year and their potential offsite impacts. Washington Administrative Code (WAC) 246-247 imposes requirements similar to those in 40 CFR 61, Subpart H, except that the 10-mrem/yr dose standard includes the dose resulting from radon emissions from other than naturally occurring sources. The following summarizes information that is provided in more detail in the 1998 air emissions report (DOE/RL-99-41), which addresses both EPA and Washington State regulations.

The 1998 air emissions from monitored Hanford Site facilities resulted in a potential dose to a maximally exposed individual at Sagemoor of 0.013 mrem (1.3×10^{-4} mSv), which represents <0.13% of the 10-mrem/yr standard. The Clean Air Act of 1986 requires the use of CAP-88 (EPA-402-B-92-001) or other EPA-approved models to demonstrate compliance with the standard, and the assumptions embodied in these codes differ slightly from standard assumptions used at Hanford for reporting to DOE via this report. Nevertheless, the result of calculations performed with CAP88-PC for air emissions from Hanford facilities agrees well with doses calculated for this report using the GENII code (0.015 mrem, or 1.5×10^{-4} mSv, for air pathways).

The December 15, 1989 revisions to the Clean Air Act (40 CFR 61, Subpart H) require DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE, Washington State, and EPA have interpreted the regulation to include diffuse and unmonitored sources as well as monitored point sources. The EPA has not specified or approved methods for estimating emissions from diffuse sources, and standardization is difficult because of the wide variety of such sources at DOE sites. Estimates of potential diffuse source emissions at Hanford have been developed using environmental surveillance measurements of airborne radionuclides at the site perimeter.

During 1998, the estimated dose from diffuse sources to the maximally exposed individual at Sagemoor was 0.025 mrem (2.5×10^{-4} mSv), which was greater than the estimated dose at that location from stack emissions (0.013 mrem, or 1.3×10^{-4} mSv). Doses at other locations around the Hanford perimeter ranged from 0.006 to 0.04 mrem (6×10^{-5} to 4×10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1998 was well below the EPA standard.

5.0.4 Collective Dose to the Population Within 80 km (50 mi)

Exposure pathways for the general public from releases of radionuclides to the atmosphere include inhalation, air submersion, and consumption of contaminated food. Pathways of exposure for radionuclides present in the Columbia River include consumption of drinking water, fish, and irrigated foods and external exposure during aquatic recreation. The regional collective dose from 1998 Hanford Site operations was estimated by calculating the radiological dose to the population residing within an 80-km (50-mi) radius of the onsite operating areas. Results of the dose calculations are shown in Table 5.0.2. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix D (Tables D.1 through D.4).

The collective dose calculated for the population was 0.2 person-rem (0.002 person-Sv) in 1998, and remained unchanged from the 1997 population dose. The 80-km (50-mi) collective doses attributed to Hanford operations from 1994 through 1998 are compared in Figure 5.0.3. Primary pathways contributing to the 1998 population dose were the following:

- consumption of drinking water (57%) contaminated with radionuclides released to the Columbia River at Hanford, principally tritium
- consumption of foodstuffs (33%) contaminated with radionuclides released in gaseous effluents, primarily tritium from the 300 and 400 Areas and iodine-129 from the Plutonium-Uranium Extraction Plant stack
- inhalation of radionuclides (14%) that were released to the air, principally tritium emitted from the 300 Area stacks and the 400 Area, and plutonium-239,240 released from the 200 Area stacks.

Table 5.0.2. Dose to the Population from 1998 Hanford Operations

		Dose Contributions from Operating Areas, person-rem				
Effluent	**Pathway**	**100 Areas**	**200 Areas**	**300 Area**	**400 Area**	**Pathway Total**
Air	External	2.2×10^{-6}	5.5×10^{-6}	1.1×10^{-7}	5.9×10^{-7}	8.4×10^{-6}
	Inhalation	1.8×10^{-3}	1.5×10^{-2}	9.6×10^{-3}	6.3×10^{-4}	2.7×10^{-2}
	Foods	4.5×10^{-5}	1.8×10^{-3}	5.3×10^{-2}	2.5×10^{-3}	5.7×10^{-2}
	Subtotal air	1.8×10^{-3}	1.7×10^{-2}	6.3×10^{-2}	3.1×10^{-3}	8.4×10^{-2}
Water	Recreation	1.3×10^{-5}	2.0×10^{-4}	0.0[a]	0.0	2.1×10^{-4}
	Foods	9.0×10^{-4}	4.1×10^{-3}	0.0	0.0	5.0×10^{-3}
	Fish	2.6×10^{-4}	8.8×10^{-4}	0.0	0.0	1.1×10^{-3}
	Drinking water	2.1×10^{-3}	1.0×10^{-1}	0.0	0.0	1.0×10^{-1}
	Subtotal water	3.3×10^{-3}	1.1×10^{-1}	0.0	0.0	1.1×10^{-1}
Combined total		5.1×10^{-3}	1.2×10^{-1}	6.3×10^{-2}	3.1×10^{-3}	1.9×10^{-1}

(a) Zeros indicate no dose contribution to the population through the water pathway.

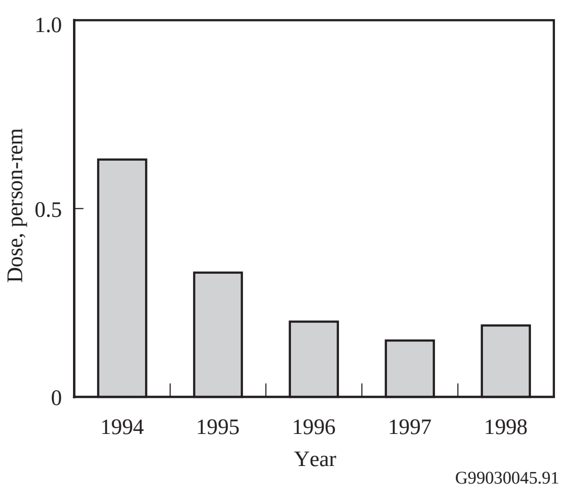

Figure 5.0.3. Calculated Dose to the Population Within 80 km (50 mi) of the Hanford Site, 1994 Through 1998

The average per capita dose from 1998 Hanford Site operations based on a population of 380,000 within 80 km (50 mi) was 0.0005 mrem (5×10^{-6} mSv). To place this dose from Hanford activities into perspective, the estimate may be compared with doses from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and x-rays, natural radionuclides in the body, and inhalation of naturally occurring radon. The national average radiological dose from these other sources is illustrated in Figure 5.0.4. The estimated average per capita dose to members of the public from Hanford sources is only approximately 0.0002% of the annual per capita dose (300 mrem) from natural background sources.

The doses from Hanford effluents to the maximally exposed individual and to the population within 80 km (50 mi) are compared to appropriate standards and natural background radiation in Table 5.0.3. This table shows that the calculated radiological doses from Hanford operations in 1998 are a small percentage of the standards and of natural background.

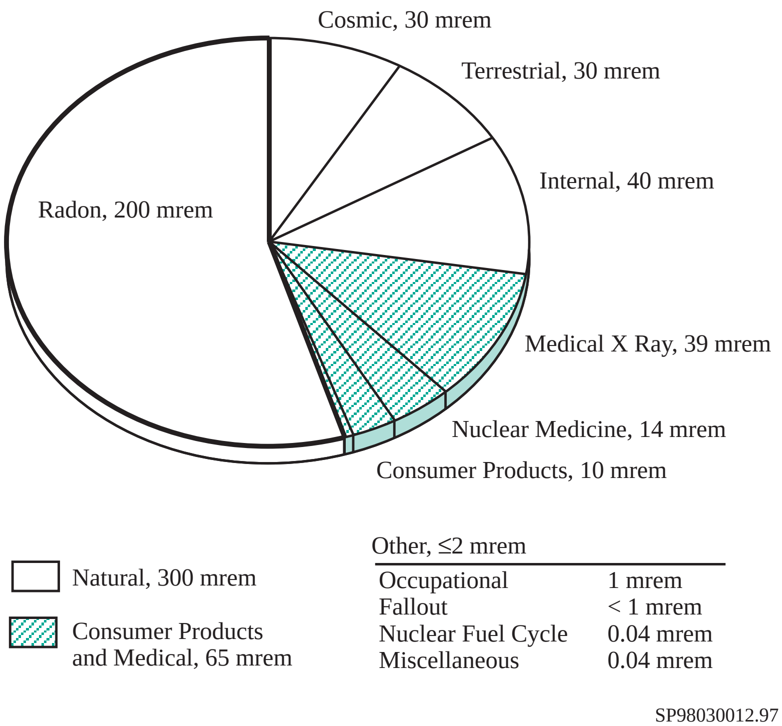

Figure 5.0.4. National Annual Average Radiological Doses from Various Sources (National Council on Radiation Protection and Measurements 1987)

Table 5.0.3. Summary of Doses to the Public in the Vicinity of the Hanford Site from Various Sources, 1998

Source	Maximum Individual	Population
All Hanford effluents	0.022 mrem[a]	0.2 person-rem[a]
DOE limit	100 mrem	--
Percent of DOE limit[b]	0.022	--
Background radiation	300 mrem	110,000 person-rem
Hanford dose percent of background	<0.01	2×10^{-4}
Doses from gaseous effluents	0.015 mrem	--
EPA air standard[c]	10 mrem	--
Percent of EPA standard	0.15	--

(a) To convert the dose values to mSv or person-Sv, divide by 100.
(b) DOE Order 5400.5.
(c) 40 CFR 61.

5.0.5 Doses from Other than DOE Sources

Various non-DOE industrial sources of public radiation exposure exist at or near the Hanford Site. These include the low-activity, commercial, radioactive waste burial ground at Hanford operated by US Ecology; the nuclear power generating station at Hanford operated by Energy Northwest (formerly known as the Washington Public Power Supply System); the nuclear fuel production plant operated by Siemens Power Corporation; the commercial, low-activity, radioactive waste compacting facility operated by Allied Technology Group Corporation; and a commercial decontamination facility operated by PN Services (see Figure 5.0.1). DOE maintains an awareness of other man-made sources of radiation, which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem (0.1 mSv) to any member of the public. With information gathered from these companies, it was conservatively estimated that the total 1998 individual dose from their combined activities is on the order of 0.05 mrem (5×10^{-4} mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1998 was well below any regulatory dose limit.

5.0.6 Hanford Public Radiological Dose in Perspective

This section provides information to put the potential health risks of radionuclide emissions from the Hanford Site into perspective. Several scientific studies (National Research Council 1980, 1990; United Nations Science Committee on the Effects of Atomic Radiation 1988) have been performed to estimate the possible risk of detrimental health effects from exposure to low levels of radiation. These studies have provided vital information to government and scientific organizations that recommend radiological dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation has actually been confirmed by the scientific community, some scientists accept the hypothesis that low-level doses might increase the probability of cancer or other health effects. Regulatory agencies conservatively (cautiously) assume that the probability of these types of health effects at low doses (down to zero dose) is the same per unit dose as the same health effects observed at much higher doses (e.g., in atomic bomb victims, radium dial painters). This is also known as the linear no threshold hypothesis. Under these assumptions, even natural background radiation (which is hundreds of times greater than radiation from current Hanford releases) increases each person's probability or chance of developing a detrimental health effect.

Not all scientists agree on how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low-level radiological doses. Some scientific studies have indicated that low radiological doses may cause beneficial effects (Sagan 1987). Because cancer and hereditary diseases in the general population may be caused by many sources (e.g., genetic defects, sunlight, chemicals, background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be conclusively proved. In developing Clean Air Act regulations, the EPA uses a probability value of approximately 4 per 10 million (4×10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 520/1-89-005). Additional data (National Research Council 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial activities (e.g., DOE facilities, nuclear power plants, chemical plants, hazardous waste sites). All of these industrial activities are considered beneficial to people in some way such as providing electricity, national defense, waste disposal, and consumer products. These government agencies have a complex task in establishing environmental regulations that control levels of risk to the public without unnecessarily reducing needed benefits from industry.

One perspective on risks from industrial activities is to compare them to risks involved in other typical activities. For instance, two risks that an individual receives from flying on an airliner are the risks of added radiological dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. Table 5.0.4 compares the estimated risks from various radiological doses to the risks of some activities encountered in everyday life. Table 5.0.5 lists some activities considered approximately equal in risk to that from the dose received by the maximally exposed individual from monitored Hanford effluents in 1998.

Table 5.0.4. Estimated Risk from Various Activities and Exposures[a]

Activity or Exposure Per Year	Risk of Fatality
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	$3,600 \times 10^{-6}$
Home accidents	100×10^{-6}[b]
Taking contraceptive pills (side effects)	20×10^{-6}
Drinking 1 can of beer or 0.12 L (4 oz) of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Firearms, sporting (accidents)	10×10^{-6}[b]
Flying as an airline passenger (cross-country roundtrip--accidents)	8×10^{-6}[b]
Eating approximately 54 g (4 tbsp) of peanut butter per day (liver cancer)	8×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Drinking chlorinated tap water (trace chloroform--cancer)	3×10^{-6}
Riding or driving in a passenger vehicle (483 km [300 mi])	2×10^{-6}[b]
Eating 41 kg (90 lb) of charcoal-broiled steaks (gastrointestinal tract cancer)	1×10^{-6}
Natural background radiation dose (300 mrem, 3 mSv)	0 to 120×10^{-6}
Flying as an airline passenger (cross-country roundtrip--radiation)	0 to 5×10^{-6}
Dose of 1 mrem (0.01 mSv) for 70 yr	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford in 1998 (0.02 mrem, 2×10^{-4} mSv)	0 to 0.008×10^{-6}

(a) These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation as a result of differences in individual lifestyle and biological factors (Atallah 1980; Dinman 1980; Ames et al. 1987; Wilson and Crouch 1987; Travis and Hester 1990).

(b) Real actuarial values. Other values are predicted from statistical models. For radiation dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 5.0.5. Activities Comparable in Risk to the 0.02-mrem (2 x 10^{-4} mSv) Dose Calculated for the 1998 Maximally Exposed Individual

Driving or riding in a car 1.1 km (approximately 0.66 mi)
Smoking less than 1/100 of a cigarette
Flying 2.7 km (1.7 mi) on a commercial airliner
Eating approximately 4/5 tbsp of peanut butter
Eating one 0.18-kg (0.4-lb) charcoal-broiled steak
Drinking approximately 1 L (1.1 qt) of chlorinated tap water
Being exposed to natural background radiation for approximately 19 min in a typical terrestrial location
Drinking approximately 0.056 L (<2 oz) of beer or 0.02 L (0.6 oz) of wine

5.0.7 Dose Rates to Animals

Conservative (upper) estimates have been made of the radiological dose to native aquatic organisms in accordance with the DOE Order 5400.5 interim requirement for management and control of liquid discharges. Possible radiological dose rates during 1998 were calculated for several exposure modes, including exposure to radionuclides in water entering the Columbia River from springs near the 100-N Area and internally deposited radionuclides measured in animals collected from the river and on the site.

The animal receiving the highest potential dose from N Springs water was a duck that consumes aquatic plants. The water flow of the N Springs is very low; no aquatic animal was observed to live directly in this spring water. Exposure to the radionuclides from the springs cannot occur until the spring water has been noticeably diluted in the Columbia River. The assumption was made that a few aquatic animals might be exposed to the maximum radionuclide activities measured in the spring water (see Table 4.2.4) after a 10-to-1 dilution by the river. Radiological doses were calculated for several different types of aquatic and riparian animals, using these extremely conservative assumptions and the CRITRII computer code (PNL-8150). If a duck spent 100% of its time in the one-tenth-diluted spring water and consumed only plants growing there, it would receive a dose rate of 0.11 mrad/d. This hypothetical dose rate is 0.011% of the limit of 1 rad/d for native aquatic animal organisms established by DOE Order 5400.5. The intent of the DOE Order 5400.5 native aquatic animal organism dose limit is to protect the population of a species, not necessarily individual organisms. It is not possible for a population of ducks to live in this spring for an entire year.

Doses also were estimated using the CRITRII code (PNL-8150) for aquatic and riparian organisms based on measured radionuclide activities in river water. The highest potential dose rate from all the radionuclides reaching the Columbia River from Hanford sources during 1998 was 6 x 10^{-6} rad/d for a hypothetical muskrat and a hypothetical duck, both of which consume contaminated vegetation. The radiological dose rate to individual animals collected on the site or from the Columbia River was calculated using the maximum activities of radionuclides measured in muscle. These doses ranged from 1 x 10^{-6} rad/d for a deer to 1 x 10^{-3} rad/d for a pheasant. Neither the doses calculated based on river water activities nor the doses based on actual biota activities approach the dose limit set forth in DOE Order 5400.5.

5.0.8 References

40 CFR 61. U.S. Environmental Protection Agency. "National Emission Standards for Hazardous Air Pollutants." *Code of Federal Regulations*.

40 CFR 61, Subpart H. U.S. Environmental Protection Agency. "National Emissions Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities." *Code of Federal Regulations*.

Ames, B. N., R. Magaw, and L. S. Gold. 1987. "Ranking Possible Carcinogenic Hazards." *Science* 236:271-280.

Atallah, S. 1980. "Assessing and Managing Industrial Risk." *Chemical Engineering* 9/8/80:94-103.

Clean Air Act. 1986. Public Law 88-206, as amended, 42 USC 7401 et seq.

Dinman, B. D. 1980. "The Reality and Acceptance of Risk." *Journal of the American Medical Association (JAMA)* (11):1226-1228.

DOE Order 5400.5. "Radiation Protection of the Public and the Environment."

DOE/RL-99-41. 1999. *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 1998*. B. P. Gleckler and K. Rhoads, Waste Management Federal Services of Hanford, Inc. for U.S. Department of Energy, Richland Operations Office, Richland, Washington.

EPA-402-B-92-001. 1992. *User's Guide for CAP88-PC, Version 1.0*. B. S. Parks, U.S. Environmental Protection Agency, Office of Radiation Programs, Las Vegas, Nevada.

EPA 520/1-89-005. 1989. *Risk Assessment Methodology: Draft Environmental Impact Statement for Proposed NESHAPS for Radionuclides, Vol. 1, Background Information Document*. U.S. Environmental Protection Agency, Washington, D.C.

EPS-87-367A. 1988. *Environmental Radiation Program, 26th Annual Report, January Through December 1987*. Washington State Department of Health, Olympia, Washington.

National Council on Radiation Protection and Measurements. 1987. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 93, Bethesda, Maryland.

National Research Council. 1980. *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980*. Committee on the Biological Effects of Ionizing Radiations, National Academy Press, Washington, D.C.

National Research Council. 1990. *Health Effects of Exposure to Low Levels of Ionizing Radiation*. Committee on the Biological Effects of Ionizing Radiations, National Academy Press, Washington, D.C.

PNL-6584. 1988. *GENII - The Hanford Environmental Radiation Dosimetry Software System*. B. A. Napier, R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell, Pacific Northwest Laboratory, Richland, Washington, 3 vols.

PNL-7539. 1990. *Methodology Used to Compute Maximum Potential Doses from Ingestion of Edible Plants and Wildlife Found on the Hanford Site*. J. K. Soldat, K. R. Price, and W. H. Rickard, Pacific Northwest Laboratory, Richland, Washington.

PNL-7803. 1991. *Hanford Area 1990 Population and 50-Year Projections*. D. M. Beck, B. A. Napier, M. J. Scott, A. G. Thurman, M. D. Davis, D. B. Pittenger, S. F. Shindle, and N. C. Batishko, Pacific Northwest Laboratory, Richland, Washington.

PNL-8150. 1992. *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment*. D. A. Baker and J. K. Soldat, Pacific Northwest Laboratory, Richland, Washington.

PNNL-11472. 1997. *Hanford Site Environmental Report for Calendar Year 1996*. R. L. Dirkes and R. W. Hanf (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-12088, APP. 1. 1999. *Hanford Site Environmental Surveillance Data Report for Calendar Year 1998*. L. E. Bisping, Pacific Northwest National Laboratory, Richland, Washington.

Sagan, L. A. 1987. *Health Physics Society Official Journal: Special Issue on Radiation Hormesis* 52(5).

Travis, C. C., and S. T. Hester. 1990. "Background Exposure to Chemicals: What Is the Risk?" *Risk Analysis* 10(4).

United Nations Science Committee on the Effects of Atomic Radiation. 1988. *Sources, Effects and Risks of Ionizing Radiation*. Report E.88.1X.7, United Nations, New York.

Washington Administrative Code (WAC) 246-247. "Radiation Protection—Air Emissions." Olympia, Washington.

Wilson, R., and E.S.C. Crouch. 1987. "Risk Assessment and Comparisons: An Introduction." *Science* 236 (4799):267-270.